

A Global SLR-only Reference Frame

D. Sarrocco (1), V. Luceri (1), A. Basoni (1), G. Bianco (2)

(1) e-GEOS S.p.A. (ASI/CGS), Matera, Italia (david.sarrocco@e-geos.it)

(2) Agenzia Spaziale Italiana, CGS - Matera

Abstract

The current official ILRS products provide time series of station positions and EOPs, leaving the estimation of velocities under the umbrella of the ITRF realization.

The goal of this work is to present a global Reference Frame for the ILRS network stations obtained using only the ASI solutions contributed to the ILRS official products. The analysis has been performed using almost 30 years of data (1993 to 2021) collected from the weekly loose-constrained SINEX products for the ITRF2020 evaluation project. The estimates from the historical series were obtained through the Globk software, part of the Gamit/Globk software, natively built for GPS analysis but adjustable for a multi-technique analysis. The approach used for Globk will be discussed, describing the workflow, the configurations, and the results of the comparison with respect to the newest ITRF2020 Reference Frame, showing a good agreement with it.

1. Introduction

The study of Earth's crust movements is of fundamental importance in many scientific fields and for many applications. It allows, for example, to define models of sliding of the Earth's and oceanic plates in order to accurately locate areas of high or low seismic activity, to evaluate the shift of the geographical poles relative to the Earth's rotation axis, in order to correctly formulate constraints between different Earth reference systems, or even to accurately evaluate mutual variations in terms of position and velocity between different points on Earth. The use of the satellite laser ranging (SLR) technique allows for monitoring the position of specific laser stations over time "anchored" on a specific portion of the Earth's crust. The historical analysis of position then allows to obtain a velocity vector, indicative of the station's displacement, which when combined with "nearby" stations produces an indication of the variation of tectonic plates in a certain portion of the Earth's crust. The analysis, carried out by considering the full SLR dataset for each laser station of the global network, is extended over multi-decade time span and allows the reconstruction of global velocity vectors at the current state. The results produced in this study were obtained through the use of the Gamit/Globk software developed by MIT (see [1] and [2], <http://geoweb.mit.edu/gg/>) in combination with the Matlab tools `tsview.m` and `velview.m` (<http://www-gpsg.mit.edu/~tah/GGMatlab>).

The definition of the velocity field was realized using the weekly products generated by the ILRS Analysis Centers of the Italian Space Agency at the Matera Space Geodesy Center (ASI/CGS) released in SINEX format for the period 1993-2021. The weekly products are obtained processing the SLR measurements in intervals of 7 days to generate loosely constrained solutions of station coordinates and daily Earth Orientation Parameters (EOP).

The models used and the settings chosen as well as the results obtained will be described in the following chapters.

2. Gamit/Globk Software

The Globk is a Kalman Filter based software for combining data from geodetic techniques. As inputs it uses the estimates (and the associated covariance matrices) of station coordinates, EOPs and orbital parameters with loose (or tight) constraints on global parameters.

Although the program primarily serves as a combination program for the outputs generated by the Gamit software in relation to GPS observations (Gamit/Globk), it can be used independently of the Gamit software, starting directly from the estimates and associated covariance matrices in SINEX formats from different techniques.

In particular, it is possible to use it to generate two kind of solutions:

- 1) "Time series" solution, i.e. position estimate for each arc and each station;
- 2) "Reference Frame" solution, i.e. unique estimate of position and velocity at a date for each station.

The generated solutions can maintain a "loose" condition or can be constrained to a reference frame (e.g. ITRF2020) with the Helmert parameters estimated minimizing the station residuals of a subnetwork. The subnetwork is selected using different methods:

- 1) putting "tight" constraints (finite constraint method) on a set of specific "core" stations
- 2) setting loose constraints and defining manually a subnetwork of stations
- 3) setting loose constraints and let Globk choose the subnetwork of stations according to *Core Site Selection Criteria*

This third constraining method is the one suggested and followed in this study.

3. Solution setup

This section describes the input files used (SINEX files) and the *a priori* parameters, as well as the main settings used to put constraints on the solution and various criteria adopted to filter out low quality data.

The SLR time series considered in this analysis was the ASI/CGS time series built following the ILRS Analysis Standing Committee guidelines and using ITRF2020 as *a priori* reference frame (see [3]) : more than 1400 loosely constrained weekly SINEX files.

Threshold conditions are imposed to exclude input SINEX files such that, considering them on the ongoing solution (during the Kalman Filter process), they would have too high adjustment on the station coordinates or in the rotation of the whole network w.r.t to the *a priori* and to the current solution (see Table 1).

Selection Criteria	Max residual adj. w.r.t. A Priori	Max «whole» rotation w.r.t. current solution
	0,5 m	10 mas

Table 1: Threshold Criteria

The parameters to be estimated are defined putting an *a priori* $\sigma > 0$ in the setup. For the two solutions (historical series and velocity field), the values reported on Table 2 were used.

Parameter to Estimate	σ Positions (up/east/north)	σ Velocities (up/east/north)
Position only	1 m	-----
Position&Velocities	1 m	0,1 m/yr

Table 1: Parameters to be estimated

With the setting described in the previous tables, two loosely solutions are generated: a “Time Series” solution of station positions and a “Reference Frame” solution. In order to constrain the solution, it is possible to decide the Helmert parameters to be estimated during the minimization of the residuals of the subnetwork of stations. As mentioned above, in this study the subnetwork selection is done through an iterative process. The Helmert parameters estimated and the main selection criteria are reported in Table 3.

1) Helmert Parameters to be estimated	Trans/Rotation/Scale
2) Core Site Selection Criteria	“Residual/Sigma ratio” < 3
3) UP Core Site Selection Criteria	$\frac{\sigma_h^2 - \sigma_{h_{med}}^2}{\sigma_{h_{med}}^2 - \sigma_{h_{best}}^2} < 3$

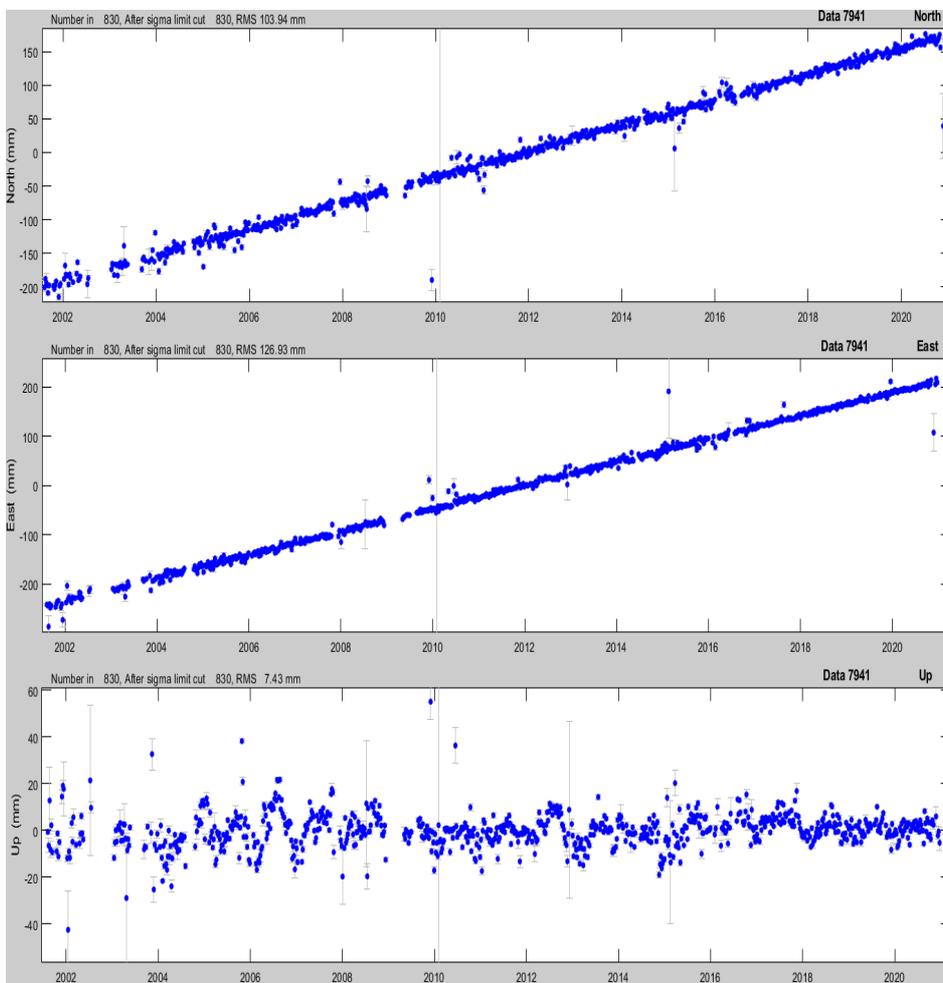
Table 3: main constraints

The last condition in Table 3 is a constraint on the Up sigma that must be satisfied by each core station. This constraint, in practice, defines that each core Up sigma cannot be too high with respect to the mean of the Up sigmas of all stations.

4. Analysis and Results

The first step of this analysis is the production of a constrained time series for each station with the aim to check the quality of the input SINEX files.

The figure below is an example of the trended time series of the Matera laser ranging station plotted with the *tsview.m* tool w.r.t. to the average estimates obtained by Globk.



Such trend plots have been compared with the one produced by IGN on the website <https://itrf.ign.fr/en/timeseries> observing a good accordance.

After removing a linear trend, the following WRMS represent the scatter of the coordinate residuals .

WRMS	
Nord	3,17 mm
East	2,38 mm
Up	5,64 mm

The editing made in the “Time Series” solution following the criteria in Table 1 is then applied when computing the “Reference Frame” solution.

The edited input files are combined to have a “unique” constrained solution for position and velocity at a specific time (2021.0) for all the station, i.e. a Reference Frame.

Fig.1 shows a visual comparison (World and Europe) between such Globk velocity field estimation and the ITRF2020 one. The agreement is quite good except some cases with big residuals due to a lack of data or due to earthquakes, since the Post Seismic Model has not been considered.

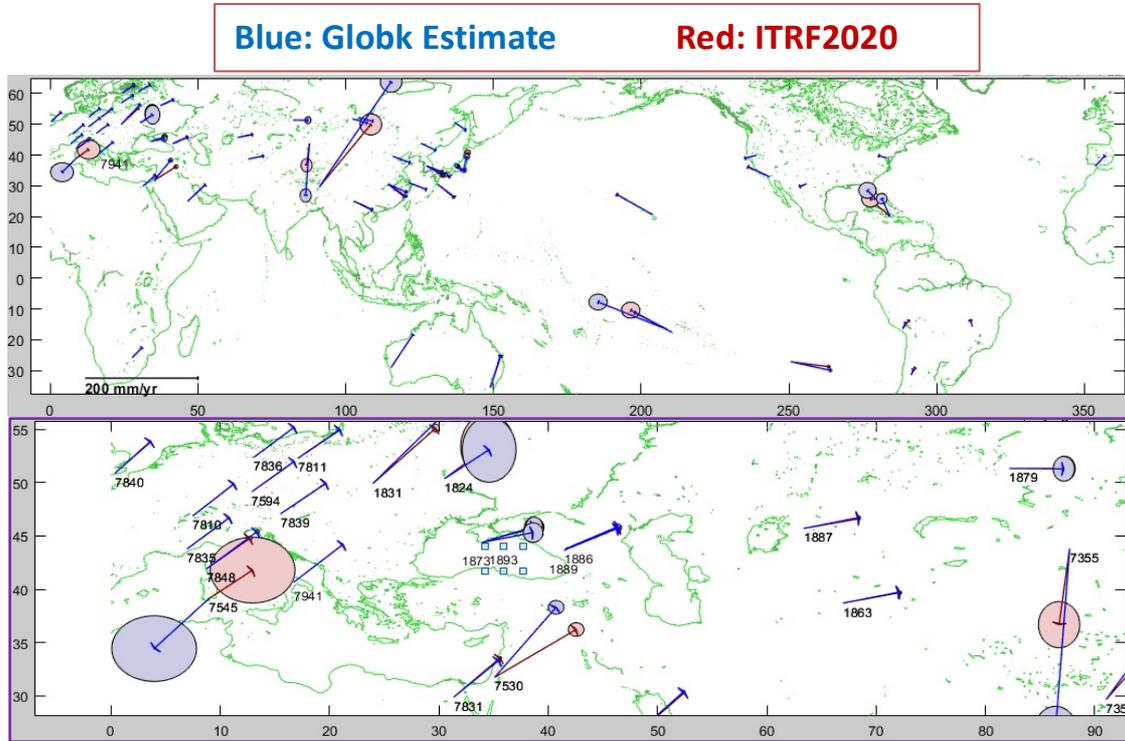


Fig. 1: Velocity Fields ITRF2020 vs Globk Estimate

In Fig. 2, it is reported the 3D-WRMS of the core sites used during the estimation of the Helmert Parameter minimizing the residuals with respect to ITRF2020.

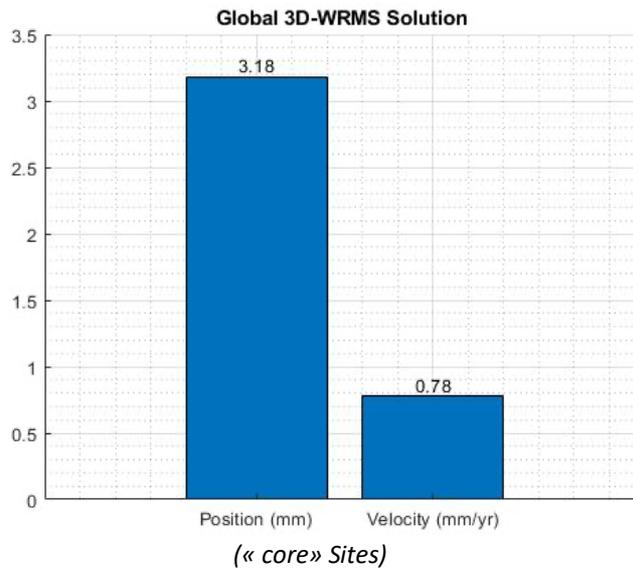


Fig. 2: Global 3D_WRMS for the SLR/Globk Reference Frame

The results of the “Reference Frame” solution is then reported on two tables (see Fig. 3) with the residuals in East (Epos/Evel), North (Npos/Nvel) and Height (Hpos/Hvel) with respect to ITRF2020.

* Position adjustments from globk.org : Date Tue Oct 25 15:02:51 CEST 2022												
* Long	Lat	Epos	Npos	dEp	dNp	E +-	N +-	Rne	Hpos	dHp	H +-	Site
* deg	deg	mm	mm	mm	mm	mm	mm		mm	mm	mm	
353.79469	36.46526	3.17	3.11	3.17	3.11	3.38	3.90	0.013	-40.60	-40.60	9.04	7824
353.79469	36.46526	0.22	4.75	0.22	4.75	1.01	1.06	0.016	-14.53	-14.53	2.47	7824
353.79378	36.46279	4.92	9.16	4.92	9.16	2.71	3.65	0.202	-39.57	-39.57	4.94	7823
312.13471	-15.77307	5.80	-3.46	5.80	-3.46	1.10	1.02	0.005	2.72	2.72	1.07	7407

* Velocity field from globk.org : RMDUP N RMNAM N : Date Tue Oct 25 15:02:51 CEST 2022												
* Long	Lat	Evel	Nvel	dEv	dNv	E +-	N +-	Rne	Hvel	dHv	H +-	Site
* deg	deg	mm/yr	mm/yr	mm/yr	mm/yr	mm/yr	mm/yr		mm/yr	mm/yr	mm/yr	
353.79469	36.46526	16.64	17.62	0.01	0.09	0.11	0.13	0.005	-3.22	-2.05	0.29	7824
353.79469	36.46526	16.64	17.62	0.01	0.09	0.11	0.13	0.005	-3.22	-2.05	0.29	7824
353.79378	36.46279	16.64	17.62	0.01	0.09	0.11	0.13	0.005	-3.22	-2.05	0.29	7823
312.13471	-15.77307	-3.22	11.43	1.00	-0.27	0.39	0.37	-0.012	-2.47	0.33	0.45	7407
291.37684	-31.50862	4.25	10.33	-3.06	-3.17	0.21	0.19	-0.012	2.06	0.77	0.22	7406

Fig. 3: Reference Frame Values

5. Conclusion

A global reference frame has been obtained using only the SLR products (ASI/CGS time series with station positions and EOPs) spanning about 30 years. The analysis used the Globk tool of the “Gamt/Globk” s/w. A good accordance of the results w.r.t to the ITRF2020 models was obtained: 3.18 mm for the Global 3D-wrms of the core site position coordinates and 0.78 mm/yr for the velocity.

This results could lead to consider the possibility to create a new product within the ILRS service to deliver a velocity field made only by SLR data to be computed and updated more frequently than the ITRF one.

At the moment the PSD model is not yet implemented even if the discontinuity due to earthquakes are considered. This will be a next step to improve the quality of the solution. The same type of analysis will be made using the official ILRS combined products.

References

- [1] Introduction to Gamit/Globk. Release 10.7 (T. A. Herring, R. W. King, M. A. Floyd, S. C. McClusky).
- [2] Globk Reference Manual, Global Kalman filter VLBI and GPS analysis program Release 10.6 (T. A. Herring, R. W. King, M. A. Floyd, S. C. McClusky).
- [3] The ILRS contribution to ITRF2020 (E.Pavlis,V.Luceri): https://itrf.ign.fr/docs/solutions/itrf2020/The_ILRS_contribution_to_ITRF2020_description_2022.09.23.pdf